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COMPARISON OF THE EFFECTS OF VARIOUS IRRIGATING SOLUTIONS ON DE--ETC(U)
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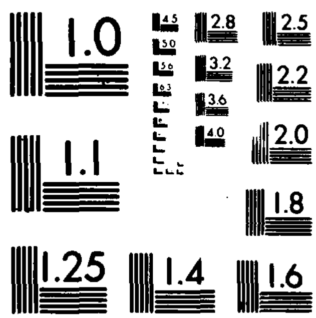
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irrigation solution did not appear to be a highly significant factor.

COMPARISON OF THE EFFECTS OF VARIOUS IRRIGATING SOLUTIONS ON DENTINE PERMEABILITY

BY

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ABSTRACT

This study evaluated the penetrating and cleansing effect of seven irrigation solutions or combinations of solutions. Fifty-six extracted teeth were divided into seven groups and irrigated during instrumentation with the various solutions. The teeth were then filled with a warm radioactive ^{125}I gel. The percentage of reduction of radioactivity caused by continued saline irrigation, drying and reinstrumentation was determined for each group. Further irrigation and drying versus additional instrumentation with larger instruments was also evaluated. How the reduction related to the original irrigation solution was statistically analyzed. The original irrigation solution did not appear to be a highly significant factor.

INTRODUCTION

It is well known that the odontoblastic processes extend into the dentinal tubules to various degrees with basically a dentinal closure of the tubules beyond the termination of the process.[1,2] The exact nature of what may remain in this tubular space prior to root canal filling, or just how the space relates quantitatively to total canal space has not received much study. One of the functions of irrigation may involve cleansing of this tubular space.

Irrigants have been tested in a variety of ways to determine what effects they have in root canals.[3-13] These effects have been studied using the scanning electron microscope (SEM),[3-6] light microscope,[7,8] culturing techniques,[9-10] radioisotopes,[11] dyes[12] and chemical products produced with pulpal tissues and dentin.[6,13] At present controversy still exists as to the best solution or solutions to use.

There are many conflicting reports in the research on irrigants.[3-16] It is generally accepted that root canal irrigants should be capable of dissolving necrotic debris, sterilizing the canal, and facilitating instrumentation.[3-10] The dentinal tubules may harbor microorganisms and toxins of microorganisms and necrotic pulpal tissues.[11,17-19] Therefore irrigants capable of penetrating the dentinal tubules, sterilizing them, and removing their toxic products may be more efficacious than irrigants not having these properties.[9,10] While many SEM studies have observed the effect of irrigation solutions on the dentinal tubules,[3-6] no study has measured the amount of debris deep within the dentinal tubules. Also, no study has compared the effectiveness of various

irrigation solutions in removing this debris from the depths of these tubules.

The purpose of this study was to determine the tubular penetrating and cleansing effect of some of the advocated irrigating solutions alone and in combination. This was done indirectly by first instrumentation and irrigation with the solutions themselves and then determining what effect this had on the subsequent placement and removal of a radioactive ^{125}I albumin tracer gel solution.

MATERIALS & METHODS

Fifty-six extracted, single rooted human teeth were collected and stored in 10% formalin. All the teeth were cut to an uniform 18mm length by removing the necessary coronal aspect with a carborundum disc. The 56 teeth were divided into 7 groups using a standard procedure of randomization.[20] Access to the remaining canal was made with a high speed #6 round bur and refined with a low speed #6 round bur. The working length was established by placing a #10 file through the canal space until it was seen at the apical opening and then substracting 1mm from this length. Group 1 was instrumented up to a #55 file using normal saline as the irrigant. Two cc of normal saline was used after each file with the canal left flooded during instrumentation. At the completion, each canal was re-irrigated with 5cc of solution. Groups 2-7 were treated by the same method as Group 1 except for the different irrigant solutions used. The irrigants were: Group 2 = 5.25% NaOCl (sodium hypochlorite); Group 3 = alternating solutions of 5.25% NaOCl and 3% H_2O_2 (hydrogen peroxide); Group 4 = 2.5% NaOCl; Group 5 = 10% citric

acid; Group 6 = EDTAC (Ethylenediaminetetraacetic Acid with Cetyltrimethylammonium Bromide)[21]; and Group 7 = alternating solutions of 2.5% NaOCl and 10% citric acid. After each tooth was instrumented and irrigated with its final 5cc of irrigant, the canal was dried using paper points. To avoid external contamination, the outside surface of each tooth was then dipped into melted sticky wax, following which a covering of pink baseplate was adapted about the tooth except for an access opening in the occlusal. The teeth were then placed into normal saline and refrigerated.

The ability of the seven solutions and combinations of solutions to widen and penetrate the dentinal tubules was measured by the use of a radioactive ^{125}I albumin tracer solution.[22] The radioactive albumin solution was prepared by mixing ^{125}I albumin* in a 2.5% gelatin solution to achieve a ^{125}I albumin content of ~ 15,000 CPM/0.02 ml (6.8×10^{-4} microcuries/0.02ml).

In order to determine a base line of radioactivity of each tooth, the radioactive albumin solution was injected into the canals up to the level of the access opening and this initial level of radioactivity was determined by placing each tooth in a plastic vial and counting each tooth in a Tracor Analytical Gamma Scintillation Counter. The radioactivity was determined as the counts per minute for each tooth.

The study was divided into two parts. Part I consisted of three procedures; irrigation, drying, and reinstrumentation. After each procedure, each tooth was placed into a new test tube and the radioactivity remaining in the canal was counted. First the canals were irrigated with twenty-five cc of normal saline. Second, any fluid

*New England Nuclear, Boston, MA

remaining in the canals was removed by the use of five paper points. Third, a size #55 file was placed in each canal to the working length, rotated 360 degrees and removed. This removed any remaining gel or debris which may have been pushed apically by the paper points.

Part II consisted of two procedures; continued irrigation alone and continued irrigation plus additional instrumentation. This was divided into four steps. Again, after every step each tooth was placed into a new test tube and the remaining radioactivity counted. First, four teeth from each group (1-7), 28 teeth, were selected randomly (Group A). They were irrigated with one cc of saline and allowed to sit with the saline in the canal for 2 minutes. They were then irrigated with an additional 20cc of saline and dried with five paper points prior to recounting. Second, this process was repeated with an additional 20cc of irrigation. Third, the remaining 28 teeth, 4 from each of the original groups, became Group B. They were flooded with 1cc of saline and then instrumented with a #60 file for 2 minutes. They were then reirrigated with 20cc of saline, dried with five paper points, and recounted. Fourth, this procedure was repeated on Group B except this time a #70 file was used.

RESULTS

Table 1 shows the mean amount of radioactivity present in the root canals of the teeth in each of the groups tested. While the mean radioactivity ranged from 9800 $\pm$s.e. (790) to 13,800$\pm$s.e. (2000) counts per minute, analysis of variance showed that there was no significant difference between the mean level of radioactivity present

in each group. In order to compare the changes in radioactivity which occurred after each treatment in subsequent parts of this study, the results were expressed as the percentage radioactivity remaining in each canal, with 100% being taken as the amount of radioactivity present initially.

Figure 1 summarizes the reduction in radioactivity which occurred after each procedure in Part I. First, irrigation with 25cc of saline reduced the initial radioactivity present in the canals 77-88%. The group showing the least removal of radioactivity by the saline irrigation was Group 6 which was the EDTAC Group, and the group showing the highest reduction was Group 7 (2.5% NaOCl/10% citric acid).

A one-way analysis of variance test was used to test if there was a significant reduction in radioactivity in the groups tested. This test showed that the different treatments showed a difference at $p<0.01$. However, post hoc analysis with Schesffe's test[20] to specifically determine where these differences were, showed that there was only a significant difference between Groups 6 and 7 ($p<0.05$).

Figure 1 also shows the effects that further sequential treatment of the root canals with paper points and a #55 file had on the amount of radioactivity remaining in the canals. Analysis of the reduction in radioactivity using two-way analysis of variance of the seven groups showed that both the use of paper points and a #55 file caused a statistically significant reduction ($p<0.01$) within each group.[20]

Drying with paper points caused a reduction in radioactivity in each group which ranged from 0.5 to 3.8% and the dependent "t" test

showed that this reduction was significant for all of the groups tested at $p<0.05$ when compared to the reduction caused by just irrigation.

As can be seen in Figure 1, reinstrumentation with #55 file caused a slight reduction in each group of an additional 0.2 to 0.9% in the amount of radioactivity present in the canals. However, due to the high standard error observed in this group, the dependent "t" test showed that only 4 of the 7 groups showed a continued reduction significant at $p<0.05$.

In Part II of this study, the effects of additional irrigation and instrumentation procedures on the amount of contamination present in the root canals after the last procedure shown in Figure 1 were investigated.

Table 2 shows that the initial amount of radioactivity remaining in the teeth in Group A was 15.7% while that in Group B was 14.5%. Analysis of variance showed that the difference had no statistical significance in relation to the prior irrigation solutions used in Part I.

Table 2 also shows that irrigation of Group A with the first 20cc of saline caused a mean 1.1% reduction in radioactivity in the canals. Continued irrigation with an additional 20cc of saline caused a further reduction of only 0.5% in Group A. In both cases the reductions were statistically significant at the $p<0.001$ level. There was no significant difference in either step in reduction in respect to which of the seven groups the teeth came from originally. This was also true for Group B with reduction being consistent irrespective of how originally irrigated during instrumentation. Group B which received both continued instrumentation and irrigation did show a much greater reduction than Group A. Use of a #60 file plus irrigation caused a 4.1% reduction while the #70 file plus irrigation caused an additional 1.2% reduction. Again, both reductions

were statistically significant ($p<0.001$). Also in respect to the reduction shown by Group A the treater reduction of Group B was statistically significant for both steps at the $p<0.001$ level.

DISCUSSION

Most previous SEM studies have shown that dentinal tubules were opened up to various degrees by the different irrigation techniques.[3-6] It was felt that placing a gel would approximate the gelatinous protein pulpal remnants thereby filling these tubules and providing a model system to show how further irrigation removes this material from the tubules. Indication that the albumin gelatin solution penetrated into the dentinal tubules was demonstrated by the finding that instrumentation with a larger instrument would remove greater amounts than by irrigation alone or by recapitulation with the last sized instrument as seen in Table 2.

The type of irrigation solution used prior to gel placement did not appear to have a significant effect on subsequent decontamination of the root canals by irrigation, paper points or reinstrumentation. In evaluation of the amounts of radioactivity removed from canals irrigated by various solutions during initial instrumentation, a statistical difference was only found between the irrigants EDTAC and 2.5% NaOCl/10% citric acid (the high and low groups). Teeth irrigated with the 2.5% NaOCl/10% citric acid combination retained the least amount of radioactivity. This could possibly indicate the tubules are obstructed more by this procedure allowing little of the radioactive gel to penetrate, but more likely it indicates that this combination debrided and opened

the dentinal tubules the greatest amount, allowing better penetration of the saline irrigant. This would also fit in better with the findings of Wayman and others[6] where the combination left very clean canals.

Teeth irrigated with the EDTAC solution exhibited the greatest amount of radioactivity remaining. This could indicate a lesser ability to open the dentinal tubules than the other solutions with the radioactive solution being bound to the debris in the tubules and thus more difficult to remove. More likely since EDTAC's main action is on the inorganic portion of the dentin, it leaves behind a more highly etched surface which functions to retain a greater amount of the ^{125}I radioactive albumin during irrigation. This concept would conform better with the highly cleaned walls and open tubules shown by McComb and Smith,[4] and Goldberg and Abranovich.[5]

Our results also indicated no difference in the effectiveness of all other solutions when comparing them with themselves or with either EDTAC or 2.5% NaOCl/10% citric acid. This would relate best with the results of Baker and others,[3] McComb and Smith,[4] and Trepangnier and others,[13] but does not relate well with Marshall and others,[11] Cohen and others,[12] or Svec and Harrison.[7] But all these studies were basically evaluating just what could be shown by microscopes to remain on the surface of the canals after irrigation. In this study an attempt was made to relate how significant this superficial debris left in the canals is in relation to what debris is left in both the canal and the tubular spaces.

Under SEM, the ability of an irrigant to remove root canal debris

has been related 1) to smoothness demonstrated on the root canals surface, and 2) to increased diameters of the dentinal tubules.[3-6] However, a false impression may be created under SEM analysis since how well a solution widens the outer dentinal tubules may not relate well to its cleansing of the tubules. For example, EDTA may remove inorganic material opening the tubules but still leave all the organic material in the tubules. Contrary to this, NaOCl, while having the ability to dissolve the organic material, may be blocked by inorganic material from reaching it. This study appears to indicate that this is what happens, or that by working together they remove both inorganic and organic materials leaving canals which are more easily cleansed.

McComb and Smith[4] reported most canals demonstrated a smeared layer with scattered debris. To evaluate the importance of the scattered debris reinstrumentation with the last file, as shown in Figure 1, was used to see if a statistically significant reduction in radioactivity could be demonstrated. A reduction was demonstrated at $p<0.05$ in 4 of the 7 groups (Groups 1, 3, 4, 7), however, no significant decrease was demonstrated in EDTAC, 5.25% NaOCl, or 10% citric acid (Groups 2, 5, 6). Whether this smeared layer is of clinical significance has yet to be demonstrated. The indication by this study is that the amount of debris and material left in the well-instrumented and irrigated canal may be basically insignificant when compared to the total volume of debris and material left in the tubules.

Following drying and recapitulation, continued irrigation alone was effective in reducing radioactivity, but irrigation with enlarging

instrumentation was almost 4 times (5.3% vs. 1.6%) as effective as seen in Table 2. In nonvital cases, it seems possible that bacteria and toxins may remain within the dentinal tubules during intra-appointment periods. Therefore, in cases of flare-up, further instrumentation with irrigation may be more effective than irrigation alone.

In commenting on the statistically significant findings of drying with paper points, it must be noted that although there is a constant reduction which accounts for statistical significance, the actual amounts of radioactive reduction were only between 0.5-3.7%. This would also relate to the reinstrumentation with the last instrument which reduced radioactivity only between 0.2-0.9%. When these figures are related to the 11-19% total amounts remaining, it may be said that while of theoretical significance, practically they do not appear highly significant.

Summary and Conclusions

Fifty-six single rooted human teeth were irrigated during instrumentation with various solutions. They were then filled with a radioactive ^{125}I gel, re-irrigated with saline, dried with paper points and reinstrumented. An evaluation was made of how the original irrigation may relate to the cleansing ability of the canal space and tubules to each of the original irrigants used.

Irrigation with 25cc of saline, drying with five paper points and reinstrumenting with the last instrument was significant in consistently removing a considerable percentage of the remaining radioactivity.

The amount of radioactivity removed by these procedures was essentially equal for all the solutions tested. The only statistically significant difference in relation to irrigant used was between the canals showing the most and least removal of radioactivity, i.e. those irrigated with EDTAC and a combination of 2.5% NaOCl/10% citric acid.

It was found that continued instrumentation with a larger sized instrument plus irrigation with 20cc of saline removed a statistically greater amount of radioactive material than irrigation with 20cc of saline alone.

It was concluded: 1) that various irrigants do cleanse and open tubules to different degrees, but clinically this difference would appear of minimal significance; 2) after the initial irrigation with up to 25cc of saline, continued irrigation with saline is not highly effective; 3) continued instrumentation plus irrigation is more effective in removing tubular contents than irrigation alone.

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LEGEND

Figure 1 Percent radioactivity remaining in canals after sequential treatments. Each bar shows the mean ± s.e. of the 8 teeth in each group. The 100% level of radioactivity in each tooth was based on the initial amount of ^{125}I introduced into each tooth at the start of the experiment.

Group 1 = saline

Group 2 = 5.25% NaOCl

Group 3 = 5.25% NaOCl/3% H_2O_2

Group 4 - 2.5% NaOCl

Group 5 = 10% Citric Acid

Group 6 = EDTAC

Group 7 = 2.5% NaOCl/10% Citric Acid

TABLE 1

Initial Amount of ^{125}I Radioactivity Present in the Root Canals of Each Group of Teeh

Group	Mean Radioactivity (Counts/Min) (a)	±s.e. (b)
1	13,300	1,550
2	11,000	980
3	13,800	2,000
4	11,500	1,700
5	9,800	790
6	9,800	940
7	12,400	1,170

(a) Mean of eight teeth. Radioactivity was expressed as counts per minute determined by counting in Tracor Gamma Spectrophotometer.

(b) Standard error of the mean.

TABLE 2

Effect of Additional Irrigation and Instrumentation Procedures on the Reduction of Radioactivity Present in Root Canals

	% Initial Radioactivity	% Radioactivity in Canal		Total % Change From Initial Level
		1st Procedure (t_1)	2nd Procedure (t_2)	
Group A* (t_a)	15.7±1.4	14.6±1.3	14.1±1.3	1.6±0.2
Group B* (t_b)	14.5±1.0	10.4±0.8	9.2±1.0	5.3±0.3

*Mean s.e. of 7 groups containing four teeth from each irrigation group in Part I.

Independent "t" test: df = 52 t_1 = -13.52 $p<0.001$ t_2 = -13.57 $p<0.001$
Dependent "t" test: df = 26 t_a = 4.97 $p<0.001$ t_b = 9.74 $p<0.001$

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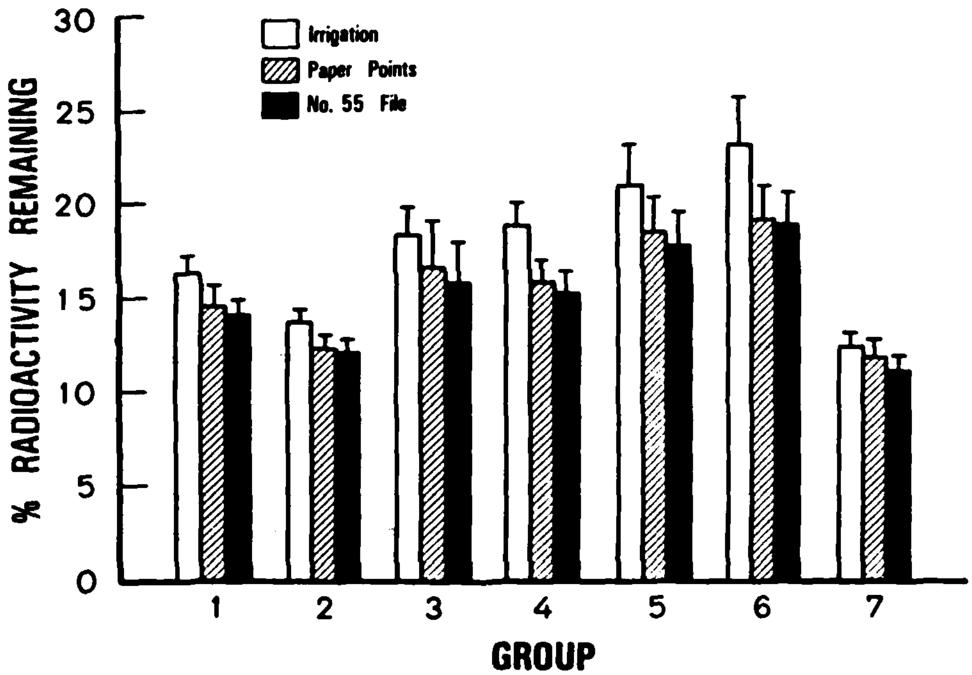
Irrigation
Paper Points
No. 55 File
% RADIOACTIVITY REMAINING
30
25
20
15
10
5
0
1
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6
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GROUP

FIGURE 1